Optimization of biogas production with water hyacinth

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DECLARATION

I certify that this dissertation does not incorporate without acknowledgement of any material previously submitted for a Degree or Diploma in any University and to the best of my knowledge and belief it does not contain any material previously published or written or orally communicated by another person except, where due references are made in the text.

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Abstract

The water hyacinth (*Eichhornia crassipes* [Mart.] Solms) due to its high growth rate and vegetative reproduction has been classified as an obnoxious freshwater weed especially in the tropics and subtropics. It has been reported that the presence of water hyacinths in waterways results in the displacement of native freshwater plants due to intense competition for light, space and essential resources such as nutrients, restricts navigation, fishing activities, cultural and social usage by affecting water quality, harbors diseasing causing vectors, etc. However the use of water hyacinth in the production of biogas has been an appealing solution to control the ever expanding infestation of this nuisance plant. This study therefore aimed at optimizing the biogas production from water hyacinth by enhancing the hydrolysis process. This study also attempted to investigate the optimum nutritional state (i.e. C/N and C/P ratios) required for effective biomethanation and to evaluate the kinetics of anaerobic digestion.

This study was conducted using six numbers of batch bed barreled digesters each having a capacity of 45 l. For this study aerial parts (stems and leaves) of water hyacinth were used as the substrate with fresh cow dung mixed in the ratio of 2:3 by wet weight (w/w). Several parameters such as TS and VS were measured once a week while TOC, TN and TP were measured every 2 weeks. Biogas production rate, pH and temperature were measured on a daily basis. The study was conducted at ambient mesophillic temperature for a period of 4 months.

Both C/N and C/P ratios decreased after mixing with cow dung having a very low C/N and C/P ratio of 8 and 165, respectively. The C/N ratios did not approach to the optimum range of 20-30. Nevertheless the C/P ratios exceeded the optimum ratio of 167 required to enhance biogas production. However gas production commenced from all digesters within 3 days of the study (i.e. a production rate of 0.73-1.35 l/kg/day was recorded).

This study showed that substrates having TS and VS contents in the range of 63-77 g/l and 45-50 g/l, respectively produced biogas more efficiently. Higher gas production rates were obtained from the substrates in the f-1 digester (i.e. digester containing the hyacinths grown in a nutrient solution containing 28 TN mg/l and 7.7 TP mg/l) particularly during the period of 14^{th}-27^{th} day. f-1 digester had the highest C/N ratio of 16, with an optimum initial pH of 7.28 and temperature of 30.3°C to account for optimum biogas production.

This study concluded that cow dung and water hyacinth mixtures produced biogas even though the C/N ratios were not within the optimum range of 20-30. Nevertheless higher biogas productions were reported from substrates having higher C/N ratios of 16. Chen and Hashimoto model fitted well with the experimental data except for a few initial values since the correction for the temperature, pH and mass transfer were not accounted. Kinetic constants μ_m and K for the substrates were in the range of 0.0074-0.0332 day^{-1} and 0.0360-0.0386 day^{-1}, respectively.

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ABBREVIATIONS

ADP	-	Adenosinediphosphate
ATP	-	Adenosinetriphosphate
B	-	Volume of methane produced at time t, per gram of substrate (VS) added
B_0	-	Volume of methane produced per gram of substrate added at infinite retention time or for complete utilization of substrate
C	-	Carbon content (mg/l)
C	-	Concentration of substrate at time t (g/l)
C_0	-	Initial substrate Concentration (g/l)
COD	-	Chemical Oxygen Demand (mg/l)
G_0	-	Biogas produced under complete digestion of influent (l)
G_t	-	Cumulative biogas at any time t (l)
K	-	Kinetic parameter (day^{-1})
K_s	-	Half velocity constant (day^{-1})
K_t	-	Reaction rate at temperature T (day^{-1})
K_{20}	-	Reaction rate at temperature 20 ^0C (day^{-1})
N	-	Nitrogen (mg/l)
P	-	Phosphorus (mg/l)
P_v	-	Volumetric methane production (l/(l/day)
R^2	-	Linear Regression coefficient
r_g	-	Rate of bacterial growth (mg/(l/l/day))
S	-	Volatile solids content at any time t (g/l)
S_0	-	Initial volatile solids content (g/l)
SRB	-	Sulphate reducing bacteria
SRT	-	Solids retention time (day)
T	-	Temperature (^0C)
TN	-	Total nitrogen (mg/l)
TOC	-	Total organic carbon (mg/l)
TP	-	Total phosphorus (mg/l)
TS	-	Total solids (g/l)
TVS	-	Total volatile solids (g/l)
UOM	-	University of Moratuwa
VFAs	-	Volatile Fatty acids
VS	-	Volatile Solids
X	-	Concentration of microorganisms (mass/ unit volume)
μ	-	Specific growth rate (day^{-1})
μ_m	-	Maximum Specific growth rate (day^{-1})
θ	-	Hydraulic Retention Time (day)
∇G	-	Activation energy
α	-	Temperature activity coefficient
θ_{min}	-	Minimum hydraulic retention time